THE STORY OF PUBLIC SECTOR IN INDIA

FERTILIZERS

D.G. RAO

PUBLICATIONS DIVISION

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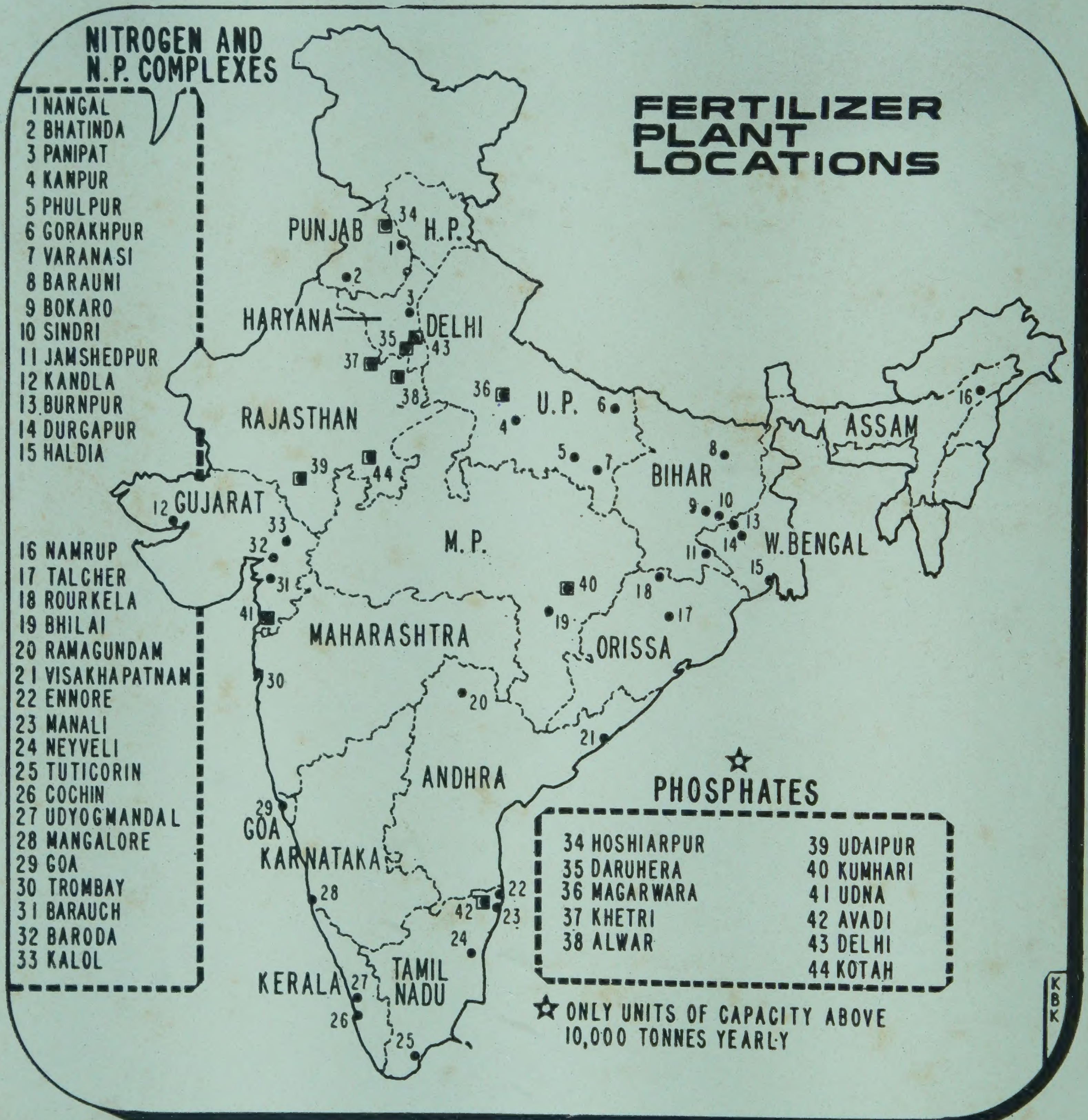

FERTILIZER PLANT LOCATIONS
NITROGEN AND N.P. COMPLEXES
1 NANGAL
2 BHATINDA
3 PANIPAT
4 KANPUR
5 PHULPUR
6 GORAKHPUR
7 VARANASI
8 BARAUNI
9 BOKARO
10 SINDRI
11 JAMSHEDPUR
12 KANDLA
13 BURNPUR
14 DURGAPUR
15 HALDIA
16 NAMRUP
17 TALCHER
18 ROURKELA
19 BHILAI
20 RAMAGUNDAM
21 VISAKHAPATNAM
22 ENNORE
23 MANALI
24 NEYVELI
25 TUTICORIN
26 COCHIN
27 UDYOGMANDAL
28 MANGALORE
29 GOA
30 TROMBAY
31 BARAUCH
32 BARODA
33 KALOL
PUNJAB
H.P.
HARYANA
DELHI
RAJASTHAN
U.P.
BIHAR
ASSAM
W. BENGAL
GUJARAT
M.P.
MAHARASHTRA
ORISSA
ANDHRA
GOA
KARNATAKA
TAMIL NADU
KERALA
PHOSPHATES
34 HOSHIARPUR
35 DARUHERA
36 MAGARWARA
37 KHETRI
38 ALWAR
39 UDAIPUR
40 KUMHARI
41 UDNA
42 AVADI
43 DELHI
44 KOTAH
ONLY UNITS OF CAPACITY ABOVE 10,000 TONNES YEARLY
KBK

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FERTILIZERS

D. G. RAO

PUBLICATIONS DIVISION
GOVERNMENT OF INDIA
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He is a chemical engineer of repute. He served from 1946 to 1951 in Fertilizers and Chemicals Travancore Ltd. on construction, commissioning and plant operations as a Supervising Engineer. Thereafter, he was selected in 1951 to serve in the Public Sector Sindri Fertilizers and since then he has been in the Fertilizer Corporation of India and worked in Plant Operations, in Research and Development, in engineering design, planning and project formulation, etc. At present, he is the Adviser (Fertilizers) in the Ministry of Chemicals and Fertilizers.

Preface

The fertiliser industry was one of the oldest branches of heavy chemical industry to have taken roots in this country.

From a very modest beginning in the 1930's, it has now grown to occupy the fourth place in the world in terms of capacity and one among the top five in terms of investment in this country. In terms of the variety of feedstocks used, products made and techniques employed, it is unrivalled even on the world scene. It has come to occupy a vital position in our economy because of the key role chemical fertilisers play in our struggle to match food and fibre supplies with our burgeoning numbers.

Our Public Sector has had a very crucial role to play in leading the way to make this industry what it is today. In earlier days, it had to shoulder the responsibilities to poineer the efforts in this commercially "risky" area as the needed resources could hardly have come from private entrepreneurship. As private investor confidence picked up, the Public Sector tended to deflect efforts on schemes which aimed at promoting self-reliance in the matter of principal inputs e.g. use of coal as a starting point for nitrogenous fertilisers, use of native pyrites in place of imported sulphur to make phosphatic, use of nitric acid in place of sulphuric acid to help solubilise phosphate rock etc. Risks in such ventures were higher than in repeating conventional lines of manufacture (primarily dependent on petroleum based imported feedstock) more extensively followed abroad. Results were, therefore, less spectacular; initial prob-

lems to be solved to stabilise output more difficult and time consuming to tackle. If, therefore, in the matter of spectacular performance pick ups, the Public Sector units have tended to come out in a rather poorer light compared to Private Sector units, this is the price they have had to pay for pioneering.

The present is a modest attempt to put this fascinating story before our ultimate "owners" so that they are made aware of the initiatives taken by their Government in promoting and fostering this industry which has a vital role to play in this country for several more years to come.

NEW DELHI
June 25, 1982

D. GRIDHAR RAO

Contents

What are Chemical Fertilizers ?

The fertilizer industry is a branch of the chemical industry which is engaged in specifically servicing the agricultural sector. The product lines of the fertilizer units provide the chemical elements which are considered as plant nutrients critical for healthy growth and desired yields of foodgrains, vegetables, fruits, oilseeds and fibres. There are some 14 elements recognised as playing a pivotal role in promoting plant growth. Of these, four carbon, nitrogen, phosphorus and potash—are required in bulk. While carbon is taken in by plants as the carbon dioxide present in atmosphere, the other three nutrients are essentially ingested as their salts through the plant roots system from the soil. Other elements required in much smaller dosages are : calcium, magnesium, sulphur, boron, zinc, copper, molybdenum, iron, manganese and chlorine. Some of the latter are also incorporated in specialised fertilizer formulations to supply specific areas where balancing inputs of one or more of these elements are recognised to be critical. The major part of the industry has, however, concentrated its attention on supplying nitrogen, phosphorus and potash in the form of chemical carriers containing one or more of these elements in regulated proportions.

Evolution of the Industry in India–The Pioneers

The chemical fertilizer industry made its first appearance on the Indian scene when a bone acidulation unit was set up in Ranipet, Madras in 1906. This manufactured, for the first time, a primary carrier for phosphorus (single superphosphate) and had a capacity to furnish about 6400 tonnes per annum of

P_2O_5*. Small amounts of ammonium sulphate were recovered as by product from coke ovens at Tata Steel Mills, Jamshedpur from 1931 onwards. This constituted the first chemical fertilizer in this country to furnish nitrogen (N).

The first chemical plant which attempted to fix nitrogen from atmosphere as ammonia and convert it into ammonium sulphate to be used as a fertilizer was set up in Belagula, near Mysore, around 1941. This plant came up at the initiative of the then State Government of Mysore and could thus be termed as the first public sector unit to enter the fertilizer field. Compared to the modern giant chemical complexes, the unit at Belagula was miniscule in size—yielding about 5 tonnes of ammonia daily which could be fixed as 19.4 tonnes of ammonium sulphate.

The second nitrogenous fertilizer unit, which went into production in 1947, was an interesting chemical complex set up at Udyogamandal, near Alwaye, in the then State of Travancore. This plant used wood (perhaps for the first time in the world) as the source material for the gas which ultimately yielded ammonia. The ammonia was combined partly with sulphuric acid and partly reacted with carbon dioxide and then with natural gypsum (from a deposit around Trichinopoly) to manufacture ammonium sulphate. The unit was set up under active patronage from the then State Government of Travancore, though managed through a managing agency system with capital subscription from public.

The first large scale wholly Government owned and managed public sector unit to start operations in this industry was the Sindri fertilizer project which was set up by the Central Government between 1948 and 1951. The decision to set up such a unit was taken in the wake of the great famine which swept

*P_2O_5 stands for phosphorus pentoxide, which is the equivalent unit in which active ingredient in phosphorus carrying fertilizers (phosphatics) is designated in this country. In some countries it is measured in terms of P (Phosphorus) only.

Bengal in 1943. It was realised that recurrence of such distress conditions could be avoided only by building up the country's potential for foodgrains production, and that a very necessary input for stimulating and sustaining such effort was to make available adequate agricultural inputs like chemical fertilizers.

Expanding needs and the Public Sector Nitrogenous Units

At the time Sindri was planned, it was considered that just one big concentrated capacity at that location should be sufficient to meet the entire country's then assessed needs for nitrogenous fertilizers. It, however, soon became apparent that many more such units would have to be progressively added, if one were to keep pace with the expanding requirements of fertilizers in this country. Governmental committees were set up to go into details of new locations and capacities to be planned. As a sequel to the recommendations of these expert groups, additional units were set up and went into operation in 1961 at Nangal, in 1965 at Trombay, in 1969 in Namrup and at Gorakhpur. All these units were developed under the umbrella of a single multiunit public sector corporation—the Fertilizer Corporation of India Ltd—which was formed in 1961 by merging the separate manufacturing units at Sindri and Nangal.

Apart from these, a unit was set up in Rourkela in 1962 to utilise the hydrogen from coke oven gas, and convert it to ammonia and eventually calcium ammonium nitrate. This unit formed part of the steel works complex at Rourkela. Similarly in 1966 the lignite based urea unit at Neyveli went into operation as part of the Neyveli Lignite Corporation's programme for all round utilisation of the local lignite deposits.

Private Sector initiatives which followed

While upto this period, i.e. the early part of the sixties, the initiative in setting up and operating the capital intensive nitrogenous fertilizer plants had been taken principally by the

public sector, during the sixties a number of private sector groups, or State Governments industrial development/investment agencies in partnership with such groups, set up several plants based on cheap, light petroleum feedstock, which became available as surpluses from refinery operations at that time. The growth of the nitrogenous fertilizer industry over the several five-year plan periods, with the distribution of ownership of the units, may be followed from Table 1.

The efforts which were channelised through the Fertilizer Corporation of India, over a period of 18 years since its formation, resulted in developing ten units in the public sector with an aggregate capacity of 1.85 million tonnes of nitrogen per year. In 1974, Government set up a fresh public sector unit, the National Fertilizers Ltd. to execute two new plants which were planned in Bhatinda and Panipat. This was done in the wake of an assessment that the Fertilizer Corporation of India had already in hand several dispersed operating units in various stages of operation or commissioning and its energies should be concentrated on consolidating these units and bringing them to a stable level of performance before taking up any fresh efforts at expansion.

Besides wholly owned units in public sector, Government also had predominant shareholding in a joint-sector venture, the Madras Fertilizers Ltd., and the units in the cooperative sector, the Indian Farmers Fertilizer Cooperative and the Krishak Bharati Cooperative. The former owns and operates three very successful units in Kalol and Kandla in Gujarat and Phulpur in U.P. The latter, which is a spin off unit partly owned by IFFCO, has set itself the task of developing two giant gas based ammonia/urea units in Hazira in Gujarat.

Decentralisation

In 1979 Government took a decision to reorganise the existing public sector units into several smaller and more com-

pact corporations—the Fertilizer Corporation of India (FCI) was given jurisdiction over the units at Sindri, Gorakhpur, Ramagundam and Talcher; the Hindustan Fertilizer Corporation (HFC) was formed to take over the factories at Durgapur, Barauni, Namrup and Haldia. The Nangal unit alongwith Bhatinda and Paniput plants were consolidated under the National Fertilizers Ltd. (NFL); the Trombay plant constituted a separate entity, the Rashtriya Chemicals and Fertilizers Ltd. (RCF). RCF was in addition allowed the task of putting up the 2 new Bombay High gas based ammonia plants at Thal Vaishet, to the south of Bombay.

Phosphatics and Public Sector philosophy thereon

In contrast to the situation in the nitrogenous fertilizer industry, on the phosphatics side the main initiatives in the first stage of development were mainly in the hands of private sector entrepreneurs. In the wake of the first unit which was set up in 1906 in Ranipet near Madras, a multitude of low cost small capacity single superphosphate units scattered all over the country marked the predominant trend in the development of this branch of the industry. Public sector efforts in this field were pioneered by the Fertilizers and Chemicals Travancore Limited (FACT) in 1948, first with setting up of a small scale single superphosphate (SSP) unit. This was followed later with an ammonium sulphate phosphate combination which represents the first of a variety of multi-nutrient fertilizer complexes which came to be established from then onwards. The main thrust of public sector effort in the phosphatics group has been on those manufacturing lines which tend to reduce dependence on imported raw material—rock phosphate and sulphur. Processes which substitute nitric acid for sulphuric acid as a means of breaking down and solubilising the phosphate in the rock, were adopted in Trombay and Haldia complexes of the Fertilizer Corporation of India. A process which attempts to use indigenous pyrites

in place of imported sulphur to furnish the sulphuric acid to attack rock, was used in the Sindri plant of the FCI. Sulphurous gases coming out of metallurgical operations were tapped to produce sulphuric acid for ultimate use in phosphatics production by the public sector metal refineries of Hindustan Copper and Hindustan Zinc Ltd. Most of the private sector units, however, have gone in for conventional sulphur based sulphuric acid route to phosphates; in several cases they import the phosphoric acid as an intermediate from abroad to combine it with indigenous ammonia to make various complex formulations. The stagewise growth of capacity in the phosphatics field is illustrated in Table 2.

The Current Scene

In terms of manufacturing capacity, India today is ranked the fourth largest in the world. At present there are some 33 fertilizer plants producing a wide range of nitrogenous fertilizers (supplying either nitrogen alone or nitrogen along with phosphorous and potash), and 25 small units manufacturing single superphosphate. Nine more units are under various stages of construction/commissioning. The locations of these units may be identified from the enclosed map. Some five more big size units are expected to be brought into operation this year while four more will still be under active phase of construction.

There are few countries in the world which use such a wide range of feedstocks for ammonia production, put out such a variety of products or practically have representative units in operation using such a multitude of processes and technologies. In terms of feedstock, for example, this country has or had plants which have at one stage or other used electrolysis, coke, coke oven gas, natural gas, naphtha, fuel oil, coal and lignite as source material for the hydrogen for ammonia production. (vide Table 3 for present distribution of capacity). Nitrogen has been furnished to the market as ammonium sulphate, ammonium nitrate (suitably diluted with chalk), urea, ammonium

phosphate and ammonium chloride. Phosphorous is supplied in the form of single superphosphate, triple superphosphate, diammonium phosphate, ammonium sulphate phosphate, ammonium nitrate phosphate, urea ammonium phosphate and various multinutrient granulates containing the three principal nutrients nitrogen (expressed as N), Phosphorous (expressed as P_2O_5) and potash (expressed as K_2O) in various percentages (See Table 4 for relative distribution of capacities product wise). The techniques employed are also quite varied as may be seen from details in Table 5.

The total investment on the currently working units in the public sector has been roughly estimated at Rs. 2400 crores. In the private sector the figure could be around Rs. 800 crores. This, however, does not include some of the latest massive units which are still under construction or commissioning. The investment per annual tonne of nitrogen output in the latest genre of plants works out to roughly Rs. 8400. The figure for the phosphatic units would range from Rs. 6400 to Rs. 11000 depending upon the processes and products chosen. While public sector units in general have a loan/equity ratio of 1/1, for the private sector units, permissible limits have in some cases been extended to 1/4.

Prices of straight nitrogenous fertilizers are controlled at two points. One defines a retention price which the manufacturer is allowed to retain; the other specifies the maximum retail price to the consumer. The system has been in vogue from the establishment of the first large scale nitrogenous unit in the country. On single superphosphate, the Fertilizer Association of India—whose membership covers almost all the major fertilizer producers in the country—has been allowed to regulate the prices on the basis of a tariff commission formula which covers the cost of raw materials—to which is added a fixed processing cost. Multinutrient complex prices were allowed to be independently fixed by producers till March 1976, when a P_2O_5 subsidy

was introduced, and consumer prices informally frozen product-wise. A cost and production efficiency linked retention price scheme was introduced in November 1977 whereby individual retention prices were fixed for each fertilizers manufacturing unit to cover its operating cost (calculated on the basis of normative figures for efficiencies at 80% of the rated capacity) and a 12% return on net capital block after providing for tax liabilities, debt servicing, etc. The industry, therefore, has been operating virtually under a system of administered prices.

The actual output as against installed capacity has been low by international standards as may be seen from Table 6; but over the years, the performance levels have, in general, improved, though very slowly. In the case of phosphatics, for some time high prices had proved a disincentive and low offtakes had forced manufacturers to cut back on production. Because of a consistently maintained subsidy on nitrogen, a similar trend has not been evident on nitrogen till now.

Critical appraisal of Public Sector approach from Policy angle

The review given above, would have already highlighted the initiatives which have come from the State sector/agencies in catalysing the growth of the industry. The impact has been more on the nitrogenous fertilizer side than on phosphatics. This was due to the size and complexity of the operations on individual units which called for a higher capital input and degree of skills on the nitrogenous units, as compared to the phosphatics group.

One interesting feature which might have been noted is that in all the earlier group of plants undertaken, the industry had consistently followed a pattern of using exclusively indigenous factor endowments on which to base the manufacturing facilities.

The electrolysis plants at Belagula and Nangal used hydroelectric power from nearby sources for furnishing the hydrogen for ammonia production. The earliest plant in Alwaye used wood as source of hydrogen production for ammonia and indigenous gypsum to contribute the sulphate part for making ammonium sulphate. The Sindri unit used locally produced coke and gypsum from Rajasthan for its ammonium sulphate production. The unit at Namrup used associated gas from local wells for its feedstock to supply hydrogens, while the Trombay and Gorakhpur units were planned on naphtha surpluses from crude refining operations of our own refineries, for which no ready alternative outlet was at the time foreseen. The Rourkela unit depended on extraction of hydrogen from locally produced coke oven gases. This hydrogen would have otherwise been put to use as a mere fuel in steel making. Considering that hydrogen production from primary feedstock represents the costliest step in ammonia synthesis, tapping of this cheap byproduct source represents one of the best and cheapest means of producing ammonia. Neyveli depended on locally mined lignite as the starting point for its operation.

Timely anticipations to suit changing situations

While the public sector has never fought shy of taking to the latest innovations in technology for building its units it has never lost sight of the long-term perspectives to keep the country in readiness to adapt itself to changing circumstances. The public sector units at Durgapur and Cochin were the first ones to adapt the new technological innovations which were sweeping the industry during the early seventies. It was an era when concepts of highly energy integrated large scale production units for ammonia were first brought into operation. The emphasis was on maximum energy recovery from the several heat release points in the process sequence for production of ammonia from light hydrocarbons like naphtha and natural gas. The objective was

to recover this energy at the highest level practicable; e.g. where the heat release was used for raising byproduct steam, the steam was to be generated at the highest pressure and temperature to begin with. It was then used to provide the essential power for the machinery drives in the plant and at appropriate lower pressure levels used for either heating purposes or for partaking in the chemical reactions in the process. The application of such concepts required a minimum economic size for the plant for successful string up of the needed equipment. There was thus a quantum jump in the sizes of the plants put up to conform to new system—from a level of around 300 tonnes/day multiunit plants in vogue till then, to a minimum 600 tonnes/day, later on enhanced to 850 to 1000 tonnes/day, and in the latest versions to 1350 tonnes/day. The units at Durgapur/Cochin (followed later by Barauni and Namrup II) were modelled on these concepts and compared to all other similar installations in this country, use the highest generation pressure for byproduct steam raised and used on the plant viz., 135 atmospheres as against 60 to 105 atmospheres used by others. The systems at Durgapur/Cochin also had a number of other features which individually represented the most optimum process choices in regard to pressures of operation and heat recoveries from ammonia synthesis loop; avoidance of excessive use of naphtha for steam raising for auxiliary purposes (instead depending on coal raised steam or power for the purpose), etc.

While public sector thus tried to pick out the best features consistent with overall national policies, it was not unconscious of the developing situation in the world in regard to feedstock sources. The industry tended to lean heavily on gas and naphtha as feedstock in the wake of the technological innovations which were then coming into vogue. It is to the credit of the planners at the time to have foreseen that the era of cheap petroleum based feedstock would not last for long. A time would soon come—and not in the distant future—when petroleum crude sources would shrink, prices would then tend to go beyond

our means and a severe crisis would be faced if the industry were to develop exclusively based on light petroleum feedstock. With this in the background, the options were carefully weighed. It was noted that coal was one of the resources which we could count on in the absence of oil or gas. (This was in the early seventies when the offshore gas was yet to be discovered). It was thought prudent to explore whether a viable coal processing technology could be acquired for use in this country, first as an experimental venture, to be perfected and replicated if the need was felt at the appropriat time. So, it was that public sector again was given the task of setting up the coal based units at Ramagundam and Talcher. It was a time when there were so few coal based ammonia plants operating in the world Neither was there any significant developmental work going on abroad in this field. Available technology was frozen at the two or three techniques which had been perfected before the "naphtha" wave submerged all efforts at innovation in this field. It was given to a small task force set up by Government with representatives from industry (drawn up from public sector), the ministry in charge of fertilizers, and the Planning Commission, to hold discussions and pay visits to the plants which were still working on coal based technology. The group observed for themselves the merits and demerits of various processes available and chose the most versatile among them which would particularly suit our coals here. Then followed the effort to string together a sequence of process steps which would lead from coal gasification to ammonia production incorporating as many of the modern concepts of highly energy integrated operation as feasible. Several improvisations had to be made to put these ideas together but the venture was initially confined only to two such units.

Pragmation on feedstock choice but with built—in versatility

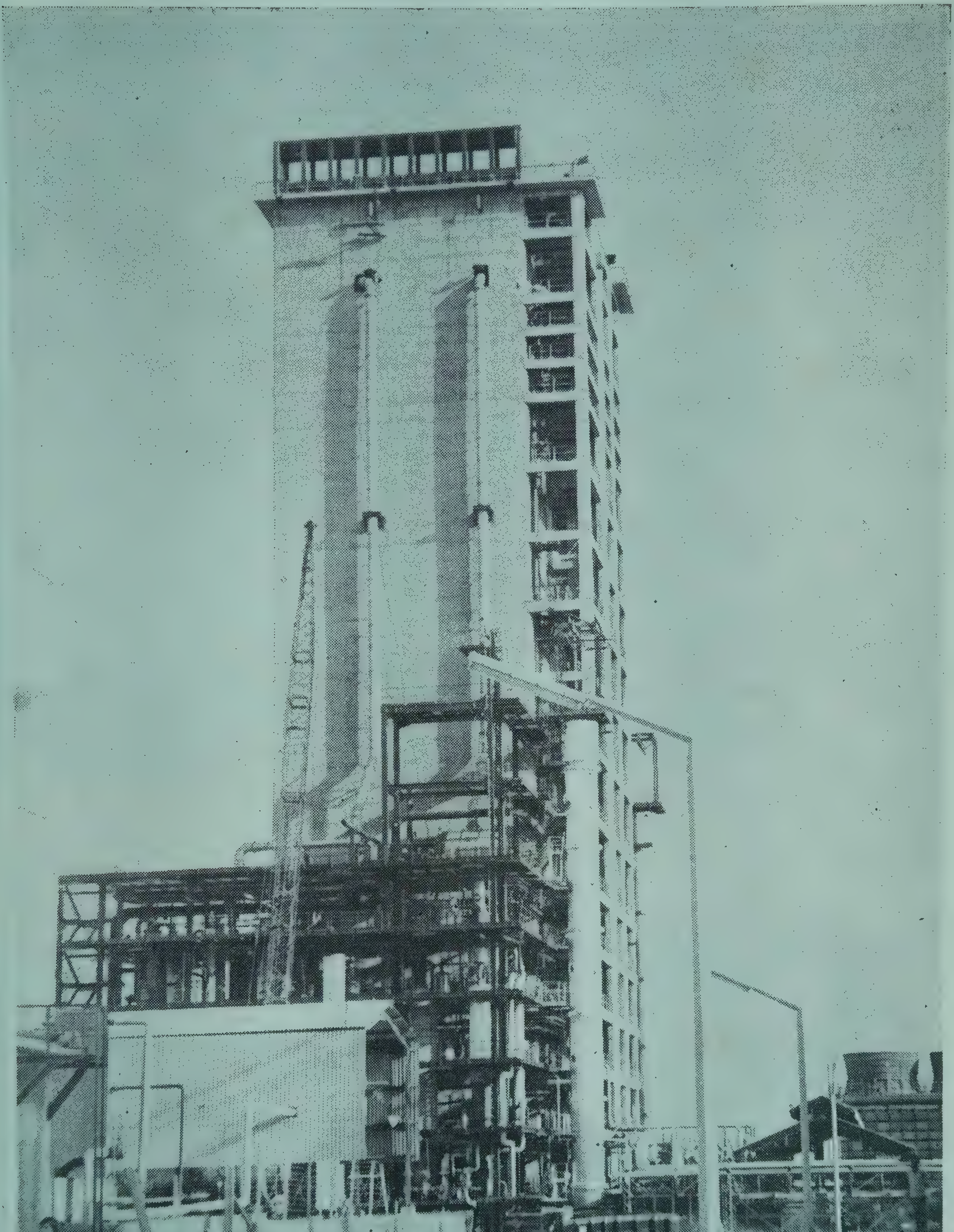
Considering that one could not afford on the one side to keep on extending naphtha capacity nor on the other hand go in for

whole scale adoption of coal based technology without acquiring sufficient experience of the same, the question arose as to what technology to use as a bridge to fill up capacity which had essentially to build up in the short term perspective, to satisfy domestic needs for nitrogenous fertilizers. The choice fell on an earlier technique which was used for gasification of petroleum feedstock—the high pressure partial oxidation process—adapted to the new concepts of scaled up operations and energy integrated systems. It was intended to use, as feedstock in these plants, the heavy residuals from indigenous refineries or from imports. Since such heavy residues often contained a high percentage of sulphur, and are not very popular as general purpose fuels due to their high potential for pollution, it was expected that they would be about the cheapest petroleum based stock available in the international market. The high sulphur content could not be very objectionable in processing these to ammonia, as there are methods of fixing and recovering it as elemental sulphur in the processing sequence. Secondly, the process used for gasifying this stock is very versatile. At a pinch it can be adapted to use either lighter feedstock like naphtha or even natural gas if domestic surpluses of either happen to occur in future. Thirdly, the process sequence is such that a coal gasification unit can be retrofitted into the system at the front end if petroleum based stock becomes exhorbitantly costly—though in such a switchover to use of coal, the plant capacity may have to be derated.

In taking to fuel oil based operations also, the public sector had to show the way. It is only after investment decisions on such units in public sector were taken that the private sector could be induced—though with reservations—to go in for fuel oil based units.

Phosphatics—tougher options

The same type of logic characterises the approach of the public sector ventures set up on phosphatics. Here, the process



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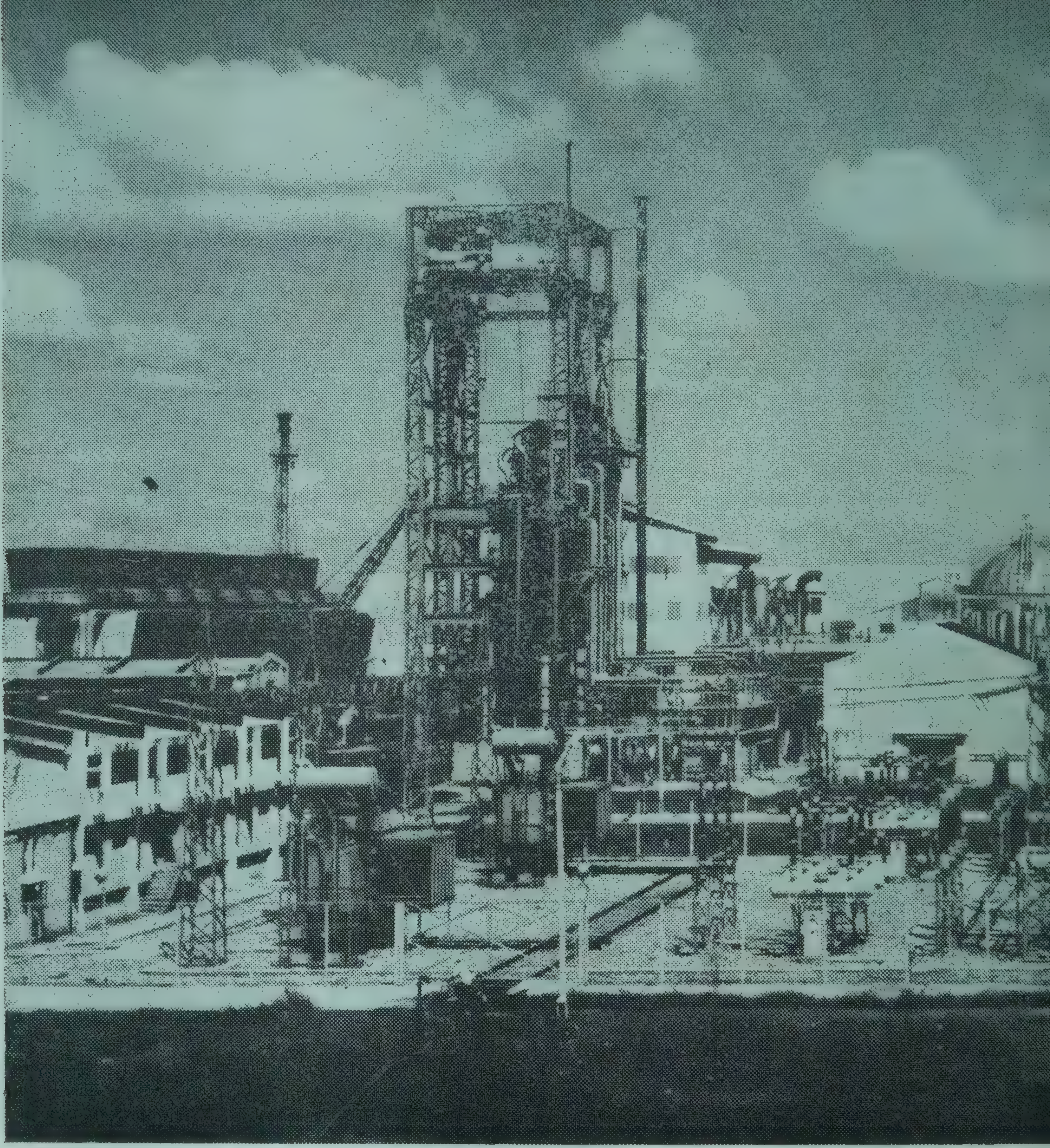
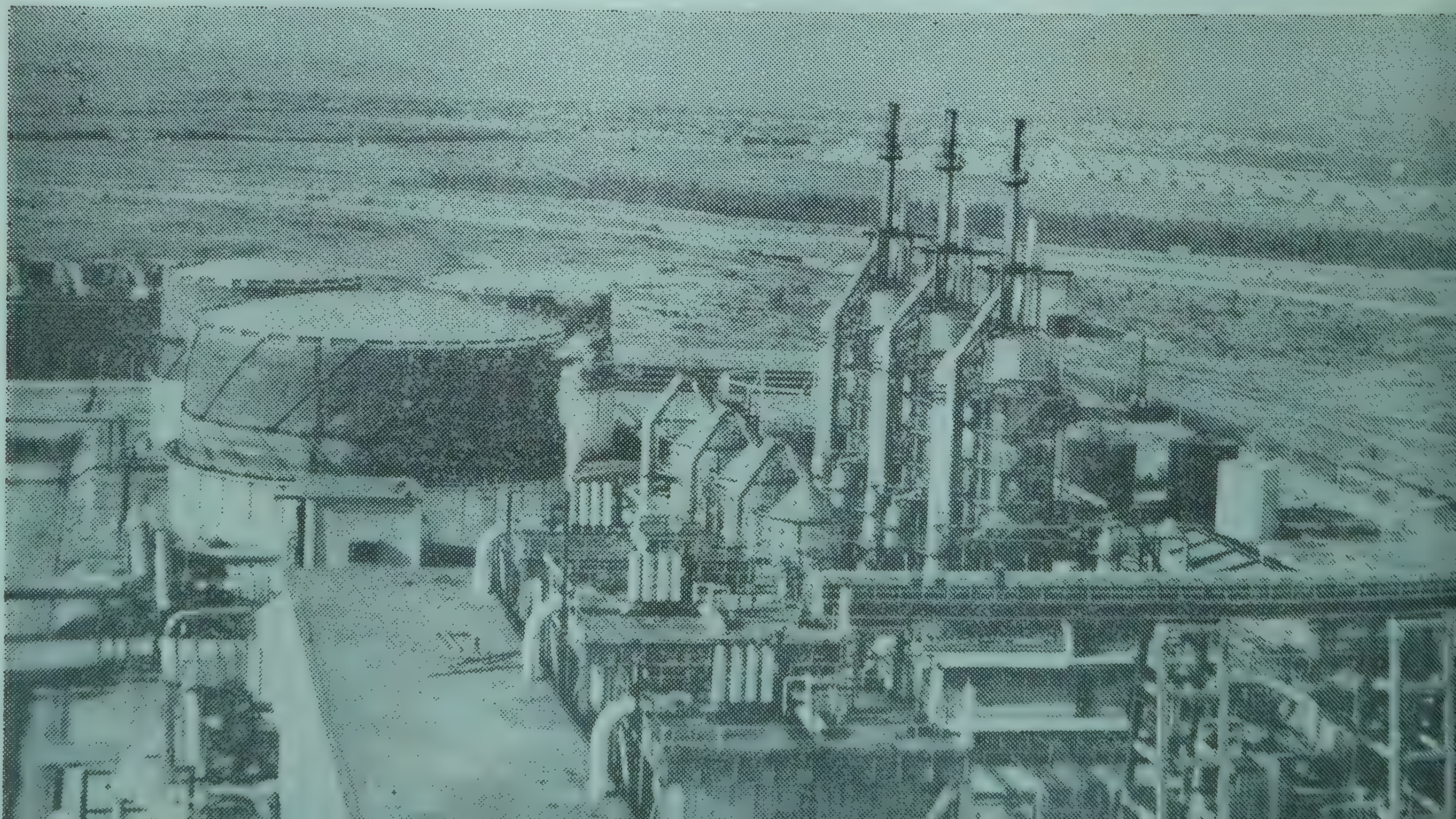
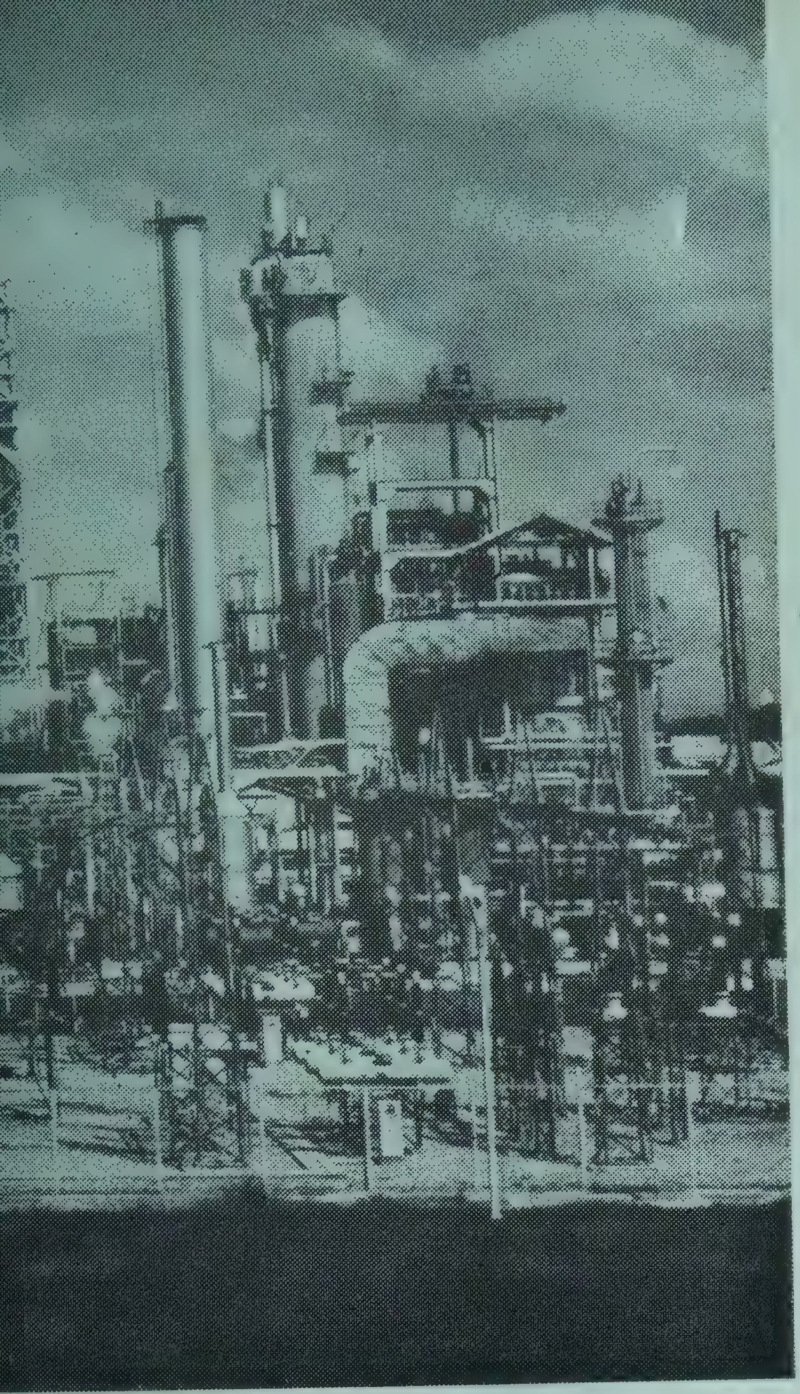


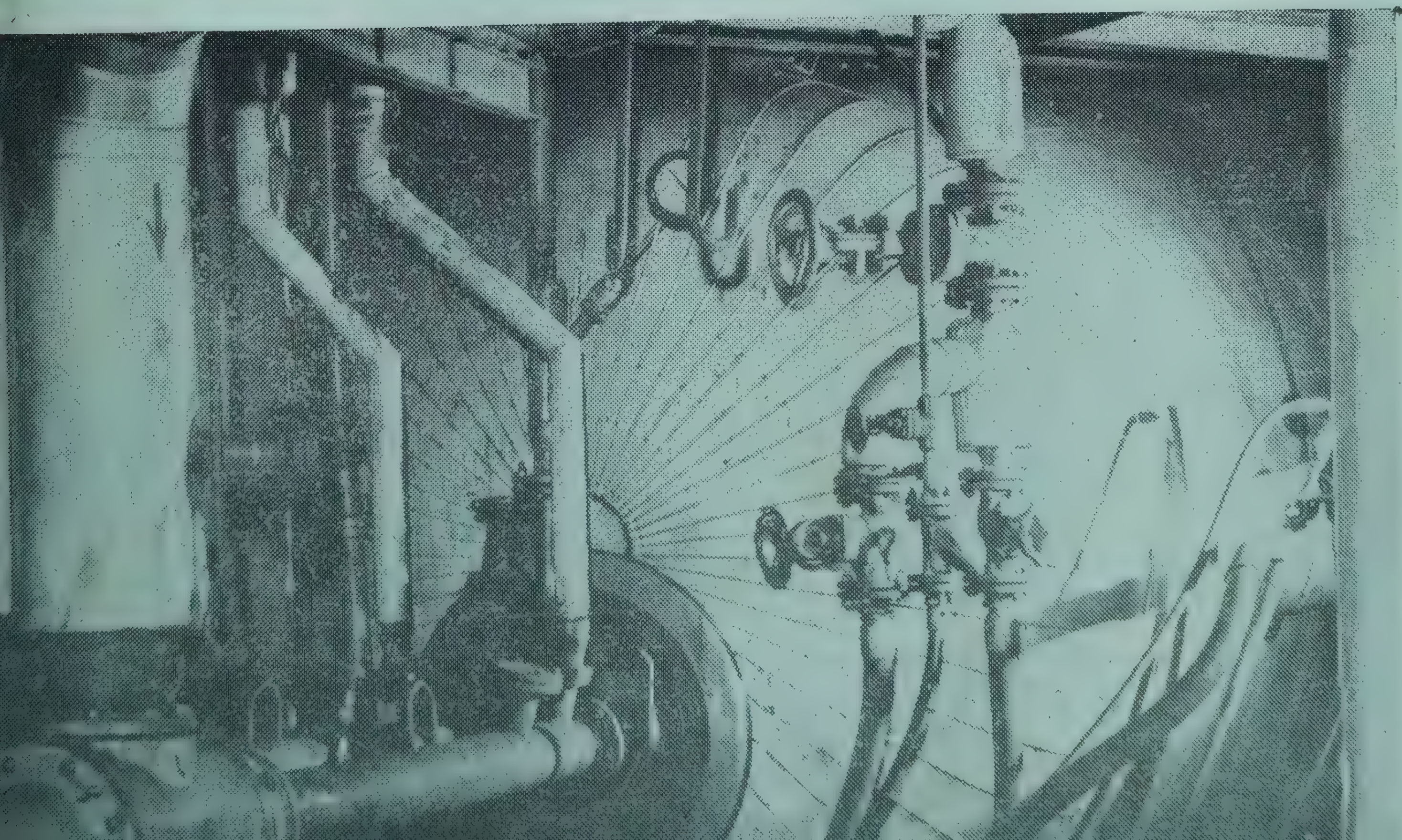
Coal gasification unit, Ramagundam





Naphtha based Ammonia Plant, Barauni

Burner head of the coal gasifier



D.M. WATER PLANT & UREA SILO

options chosen tended to those which would curtail imports to the unavoidable minimum or promote the use of non-traditional sources for one or the other of vital inputs in this branch of industry. Before one goes into more of such details, a brief explanation of the fundamental processing steps used in the manufacture of phosphatics and their relegance to our local conditions, appears relevant. In nature, phosphate occurs as water insoluble calcium salt which normally is not in a condition to supply its phosphate content to the plant root system. The phosphate in this natural mineral is released and fixed in a water soluble form by reacting it with one of the mineral acids sulphuric, nitric or hydrochloric and segregating the extracalcium. We have only limited resources of the primary mineral rock phosphate, in a form suitable for processing to soluble phosphatics. We have no identified sources of elemental sulphur which could be processed to sulphuric acid, the most widely used mineral acid for attacking and solubilising phosphate rock. However, this country does have some alternate sources of sulphur in iron pyrites, and some sulphidic ores of copper and zinc. The strategy which the public sector units have concentrated on are :

(a) Wherever copper or zinc manufacturing operations give rise to sulphur bearing gases, use these gases to produce sulphuric acid; in turn use this acid for phosphatics production;
(b) Where there are reliable or extensive sources of iron sulphides or pyrites, use these in a primary operation to produce sulphuric acid (even if the metal values have to be rejected as cinder), and base phosphatics capacity on the same;

(c) Stretch the use of available sulphur sources to the full by concentrating on production of triple super phosphate. This product is obtained by reacting phosphoric acid with properly proportionated amounts of phosphate rock. Production of phosphoric acid or its ammonium salts which are popular as phosphatics fertilizers, requires about 225 Kg. of sulphur per tonne of P_2O_5 delivered in product. Triple superphosphate will

require only around 162 Kg. of sulphur for every tonne of P_2O_5 delivered in product;

(d) Use alternate means to solubilise rock phosphate; one such is to attack rock with nitric acid in place of sulphuric acid. This method has several limitations. The plants are costlier. It is more difficult to segregate the excess calcium from the solution to the extent needed to yield a completely water soluble phosphate as in the case of, say, diammonium phosphates. The products obtained also tend to have excessive proportions of nitrogen as compared to phosphates which is not a desirable thing from the application angle. But then from the broader considerations of saving input imports, the technique would pay off, especially if the international prices for sulphur continue to harden.

Pioneering and innovation—but at a cost

In many such ventures, where some amount of "Pioneering" had to be done in the interest of long term national objectives as well as need to marry production schemes to our country's factor endowments, the initiatives have had to be taken by the public sector. Private sector inhibitions to venture on such schemes is understandable since use of non-traditional sources of feedstock normally call for more capital intensive installations than the conventional approach. Secondly, there are less number of established and proven installations abroad which have been working on the technologies needed. Therefore, the risks of delays, technical snags in adapting technology to the local raw materials, etc. are higher. The possibilities of attaining a satisfactory level of performance in the plants within a relatively short time of stabilisation, are also, therefore, less. These are formidable disincentives for an entrepreneur who has to depend largely on financial institutions for the bulk of funding. The factors touched upon above could also partly explain why several of the public sector schemes have not registered as high a level

of performance as most of the private sector ones. It would, however, be unfair to say that private sector attitudes continue to be ultra conservative and are not changing with times. Some recent investment decisions indicate to the contrary. For instance, Southern Petrochemical Industries Corporation is sponsoring a scheme for production of cement and sulphuric acid from byproduct gypsum. This has been a possibility which has been debated for a long time. Only it is being given a concrete shape. It would have the effect of virtually regenerating and recycling the sulphur used for rock phosphate solubilisation. A substantial saving in imports of sulphur will result. Similar has been the case of Bellarpur industries, Karnataka, which has successfully set up a plant for production of pure grade phosphoric acid using byproduct hydrochloric acid as the solubilising agent. This is also a step in the right direction. The acid was originally meant for use in production of sodium tripdy phosphates but due to market constraints, proposals are now being developed to use it for fertilizer production.

Technology Assimilation leads on to innovations

One other significant contribution which has been made by the public sector in the fertilizer field is to build up a broad technical base for not only mastering the intricacies of operating on sophisticated imported technology, but also to absorb the details of the technology, adapt and improvise on it, and build up the capability to replicate manufacturing units, with a substantial indigenous contribution, both in terms of supplies as well as services. This is an effort which extended over a long period, starting some time in 1951 when the first large scale fertilizer unit went into operation at Sindri. The initial efforts were confined to problem solving in the plants which makes an interesting story. An imported catalyst used in the Sindri ammonia plant for promoting reactions between carbon monoxide and steam to produce hydrogen and carbon dioxide, was getting fouled up often with

incrustrations. This was leading to a crisis on continuity of production. By experimentation, a method of rejuvenating this catalyst was perfected. The investigation as to why the incrustration was taking place led to efforts to develop a new formulation for the catalyst which could avoid such incrustration. The idea was further developed with active encouragement from the management and a full scale manufacturing plant for production of such a catalyst was set up. The effort was later extended to production of other varieties of catalysts which are vital processing media used in manufacture of ammonia. This catalyst manufacturing unit in the public sector now boasts of capabilities to manufacture at least six out of the eight catalysts traditionally used in any of the plants processing light hydrocarbons like gas or naphtha. All the catalysts are based on formulations and techniques independently developed by the same group. None of them require any licences or royalty payments to any foreign patent holder. India now ranks as one among the three or four recognised, independent and proprietary sources for catalysts used in ammonia production. Some of the plants now operating in the public sector use exclusively these catalysts.

The multifunctional approach to develoment

The story of catalyst development efforts illustrates just one facet of the activities of the R & D Group set up in Sindri. It is to be mentioned that developmental efforts which were sought to be institutionalised in Sindri aimed at evolving a multifunctional structure which should cover all aspects of the industry—from project planning, to engineering design, construction, commissioning, trouble shooting, innovating and diversifying product lines, looking for import substitution, for process adaptation to local material, for use of waste materials, byproducts, etc. At the initial stages, efforts were concentrated on absorbing the details of technology acquired, looking for developments abroad, in short, learning the ropes of the trade. This was followed by a phase where replication of some existing units

were attempted based on purely departmental efforts when expansion of some existing facilities were put up. The first major original and independent assignment which was boldly attempted was to build one part of the complex which came up at Rourkela Steel works, comprising a 1550 te/day nitric acid (55% strength) plant and 1825 te/day 21% N calcium ammonium nitrate unit. All detailing work in the scheme was done departmentally. A Dutch consulting firm was later asked to go through the completed documentation to reassure all concerned that all technical aspects were adequately covered. It is to the credit of the group that the documents were cleared with almost no amendments. Following on this, some of the simpler chemical plants like the 350 te/day ammonium sulphate unit in Namrup (based on direct neutralisation of sulphuric acid with ammonia) were attempted. Around this time (1966) Government took a review of the technological inputs which will be required for the progressive expansion of the fertilizer industry as envisaged then, and asked the two public sector engineering consultancy groups—one at Sindri and the other Fertilizers and Chemicals, Travancore Ltd. Aalwaye—to identify the gaps in technology which they would like to cover to equip themselves to build future fertilizer plants on their own. As a result of this, several process licensing arrangements were negotiated and concluded. The process details of naphtha reformer furnaces, raw gas processing facilities, ammonia synthesis systems, urea production techniques, sulphuric acid, phosphoric acid production, etc. were progressively acquired by one or the other of public sector consultancy wings. The actual contractual tie ups with consultants for each process (chosen after a comparison of processes and offers for licensing) provided for, association of Indian engineers with the work of developing the process package. It allowed them to do the detailed engineering under the consultants' supervision, and under his guidance, set up and commission the full fledged manufacturing facilities. This was a marked departure from previous practices where ready made plants used to be imported wholesale from abroad and put together in this country.

Association of Indian engineers was only for peripheral tasks such as executing civil foundations, supervising mechanical assembly at site and getting technical personnel trained in operation and maintenance of finished assemblies. The new arrangements envisaged association of Indian engineers right from the conception of the plants, active participation in development of documentation, an opportunity to go into the details of how and why provisions are worked into the scheme and the various elements are integrated and coordinated to produce a complex unit. The licences actually covered process schemes which incorporated the latest in technology, with highly energy integrated set ups, the most modern centrifugal machinery, etc. Not all consultants were willing to enter into such arrangements at the time. Many of them did not want to part with some part or other of proprietary information. Others felt that some aspects of the project should best be handled wholly by themselves without association of Indian engineers. But fortunately there were at least some others who were more responsive to our needs and aspirations. Once a breakthrough was achieved on the lines of our preferences, a model was set for future mode of execution of projects. Several consultants who would have otherwise been hesitant to get into such arrangements, were willing to fall in line for some of the later projects.

The spin offs from the effort at doing it by oneself

The effects of this mode of contracting was widespread. They not only benefited the fertilizer industry but also other feeder industries which are in one way or other related thereto. Indian engineers sharpened their skills and knowledge through such arrangements. They were able to take up confidently the task of setting up ammonia plants not only based on naphtha/gas, but also later, fuel oil and coal too. In successive assignments of the same nature, they were able progressively to reduce the quantum of guidance from the consultants abroad. Indeed many

of the foreign consultants have developed a high regard for Indian capabilities to readily grasp details, critically analyse data and come up with constructive suggestions. Our engineers have now advanced sufficiently to evolve their own standard designs for the ammonia and urea units; on such schemes, apart from paying royalties for incorporating a few of the proprietary features which had to be adapted as representing best prevailing practice, no detailed consultancy or licence payments are involved.

The amount of detail which had to go into the engineering documentation in the initial few schemes was considerable. At that stage this was needed to get Indian suppliers to attempt fabrication of several items of very sophisticated equipment for the first time. Apart from that, the engineering personnel who developed the drawings had to give field guidance on fabrication at the shops and develop an elaborate system for testing, inspection and certification too. The fabricators have also by now picked up skills sufficiently to attempt the detailed documentation on their own, once the process specification sheets are issued. As a result of this emphasis on progressive self-suffciency, fresh manufacturing facilities for several very sophisticated machinery was also developed within the country. A shining example may be found in the very high speed centrifugal compressors and drives which even now several advanced countries (e.g. U.K.) do not manufacture.

The range of experience which the Indian industry has come to acquire on building fertilizer plants is indeed unique, as may be seen from the list of processes (Table 5) which have been covered by one project or other. It would be difficult to find a parallel for this anywhere else in the world.

Trouble shooting and problem solving

While skills were being developed for putting up fresh facilities, indepth studies of the problems of existing units also were

taken side by side. There are many instances where innovative retrofit schemes were evolved to get over production bottlenecks and improve performance. As an illustrative example we had the cases of gas based ammonia unit at Sindri and the naphtha reformation plant preparing raw gas for methanol production at Trombay. Both of these units had run into limitations on securing sufficient feed gas to run the connected units at rated capacity. New systems based on use of naphtha reformers were designed to meet the specific needs of each of these units and fit them into the overall process scheme. These were very successfully commissioned. In the Trombay case the plant output picked up to 125% of its original rating. Following on the success in Sindri, the Rourkela fertilizer unit also went in for the same system to supplement coke over gas. The retrofit of the fuel oil gasification systems and adaptation of the existing gas processing facilities to the new gas composition at Neyveli, is also a success story worth mentioning. Before these were built in, the Neyveli plant had been hardly touching 60% of its rated annual capacity. The additions spectaculary improved performance to stabilise it consistently around its rated capacity. When gypsum delivered costs sent the ammonium sulphate prices to uneconomic levels at Sindri, special facilities were set up at Sindri, to augment sulphate production by direct neutralisation of pyrites based sulphuric acid. Incidental to this, two other advantages were secured. One was to increase the efficiency of the "once through" urea plant installed at Sindri by using the sulphuric acid to fix the excess unconverted ammonia which was coming from the urea reactors. Second was to use acid neutralisation to enrich dilute sulphate solution resulting from gypsum based operations whereby an incidental saving in steam consumption was also secured.

Comprehensive technical services

On the technical services side, the R&D groups provide non-destructive testing facilities for monitoring and guiding predic-

tive maintenance on fertiliser equipment without interrupting operations. They do detailed investigative studies on material failures attributable to corrosion in course of service, and recommend remedial and preventive measures or suitable substitute material which may withstand such conditions better. They develop and prescribe protective coatings for various duty requirements such as those fit for protecting floorings, foundations and buildings against acid attack, etc. They prescribe special treatment methods to prevent scale deposits or corrosion from water used for various uses in process for cooling circuits, process use, steam raising, etc. They have to be highly location specific as water characteristics change from place to place. They carry out studies on pollution emanations (both liquid and gaseous) from various process outlets and devise and prescribe containment measures. They test and certify service fitness of indigenous substitutes for miscellaneous process inputs, auxiliary supplies (silica gel, polythene bags, etc.), plant components like instruments, valves, etc.

Product diversification—salvaging value from waste

By way of diversification, the R&D groups have developed and commercialised processes for production of technical grade ammonium bicarbonate, ammonium nitrate, guanidine nitrate, sodium hexamelaphosphate, sodium nitrite and sodium nitrate, cryolite, etc. Some of the other products for which processes have been developed are : byproduct gypsum based building blocks and plaster; food grade dicalcium phosphate; sodium tripolyphosphate from some Indian rocks (which impact objectionable colour to the product); sulfamic acid, etc. All of these use intermediates manufactured in the fertilizer plants themselves as the starting material. Some of them are recovered from effluent streams of the operating plants which any way require suitable disposal measures.

Prospects and challenges for the future—cost hikes and shrinking resources

The challenges which the industry will have to face during the eighties, are formidable. Use of chemical fertilizers is catching up fast. Its pivotal role in securing higher yields to match the relentless additions to our numbers will get renewed emphasis with time. But then the cost of expanding manufacturing facilities, is also going up at a dizzy pace. The costs of inputs, especially the imported ones, like fossil fuels, sulphur, etc. have been pushed up by international cartels, who control the restricted sources for these. The price push on these is induced both by the increased demand from all over the world, as well as the dwindling reserves of these non-renewable resources. Besides this, the costs of extraction and transport have also gone up. In the eighties, therefore, we are likely to face an era of much higher costs on inputs on the one hand as well as scarce availability of some of the commodities, on the other.

The tasks before the industry would, therefore, be to see how scarce resources both on manufacturing facilities as well as on available high cost products are made to stretch to the maximum. Securing the maximum outputs from developed facilities, therefore, deserves the highest priority. On this score, our record of performance leaves a lot to be improved. The constraints have been partly technological and within the control of the manufacturing units; but a significant part has also been from factors outside the control of these units, principally on getting timely inputs of right quality and adequate in quantity. Both should be capable of improvement by better management.

Frugal use of limited resources

A second aspect on which urgent attention is needed, is to do technical audits on usage of scarce material, both fuel and

feedstock, and to take such measures as would ensure their use to maximum advantage.

Making the most of high cost inputs

The third set of measures needed is to see that at the application end, the maximum benefit is obtained from whatever costly inputs go into the soils. This requires a multi-pronged strategy. The ideal approach would be to assess the needs of each crop at each location in terms of its minimal nutrient requirements by proper soil and crop analysis. As far as feasible inputs should be adjusted to meet the minimum needs of such nutrients so that wastages due to over dosages or misapplication are minimised. It is conceded that the assessment of such needs and making such custom based prescriptions can be a stupendous task in a vast stretch of country such as ours. But then the need for such an exercise will be felt more and more intensely as the input prices rise. There is an established tradition among present day producers to make and sell standard multi-nutrient complex formulations with brand names to secure and keep their own chunks of market areas developed with effort and expense. The idea of custom based formulations may run counter to their interests and considerable resistance from among them can be expected in dampening these concepts. Thinking on these lines, however, has been initiated already. The suggestion is to earmark one standard formulation each as a carrier for each nutrient, e.g. urea as the main carrier for N, diammonium phosphate for P_2O_5 and potash granulated with molten urea as the carrier for K_2O. These standard carriers can then be produced in pills/granules of same standard size. It would then give infinite facility to blend these granules in any proportion needed to satisfy specific needs of each crop and location or even varied compositions to be applied as the same location in split dosages. This is also in consonance with the ideas of the agricultural experts who advocate that the nutrient application should be timed properly if the maximum benefits are to be derived from a given quantum of inputs, since some of the

chemical carriers have a tendency to loose their active elements either by leaching in the soil, by decomposition and volatilisation due to bacterial action or fixation in unavailable forms by reaction with soil elements. This brings us to another point on which considerable R&D effort will be needed in the near future—that of evolving suitable additives to the present carriers which could have the effect of inhibiting such losses and improving the actual uptake of nutrients by plants in relation to applied dosages. Some agents such as neem cake etc. have been found which could inhibit loss of nitrogen from applied fertilizers in the soils. Claims have also been made about virtues of a new coal based organic fertilizer which can also "stretch" the effectiveness of applied nitrogen by about a third. Development work needs to be urgently carried out in this field.

Foresight on feedstock planning

Advance planning is also required to soften the effects of high input prices and possible scarcity of essential imported inputs for the industry. In so far as nitrogenous fertilizers are concerned, it is fortunate that a sizeable quantity of natural gas has been discovered in offshore wells off the coast of Maharashtra and Gujarat. There appears to be promise of more such discoveries in areas as far apart as Andamans and the Godavari basin. Even the known and assessed resources are sufficient to develop a nitrogenous capacity of approximately 7.6 million tonnes per year. Plans have already been drawn to do this over a decade. If after consolidation of our experience on coal, it is found that the route is economic and viable, more coal based plants may follow in case the new gas based capacity becomes inadequate. Naphtha or imported fuel oil will no longer be used unless there be a disposal problem at a particular site which makes its use attractive. Preferably surpluses of these which may come up at coastal refineries would be exported to recoup at least partly the mounting foreign exchange outgoes on crude imports.

The policy in regard to phosphatics has to be somewhat different, since in this case our known resources of the most essential source, viz., phosphate rock, is limited, and even at the present level of consumption, hardly meets about a sixth of our requirements. We are also short of elemental sulphur. As already pointed out, our strategy on internal production of phosphatics would be to avoid use of sulphur if possible; use alternate sulphur sources such as pyrites, metallurgical sulphur bearing gases, etc. for sulphuric acid production; regenerate and recycle sulphur by using the gypsum sulphuric acid plants etc. Some interesting R&D work has been done on recovery of elemental sulphur from waste shale in Amjhore, and from byproducer gypsum. While interesting results have been obtained, the schemes for scale up and possible commercialisation will have to wait funding decisions for these developmental activities. Alternate methods of phosphate solubilisation from rock, for instance, by use of nitric acid, have not been very popular with agricultural scientists in this country because when supplied as nitrates, the nitrogen losses in soil by leaching and decomposition appear to be higher, especially for flooded paddy cultivation. There is, therefore, a need to develop techniques whereby the nitrate content in these fertilizer can be restricted by devices like separation and recycle of the nitrate. We have also some phosphate sources which are associated with other minerals like iron, oxide, silica, mangnesia, etc. which make processing by conventional methods, technically difficult. Means have to be found to either segregate the phosphate and win it in a form suitable for normal processing or to evolve new methods of attack which are specifically suited to such raw material.

Confidence in a future

Taking an overview of the industry and its evolution, one can look back with satisfaction on the healthy growth which has been secured over the years, with contributions both from the State as well as private sector. Skills and capabilities have been built up

on all aspects of manufacturing activity from concepts to commissioning and steady operations thereafter. This is no mean achievement for a country like ours which made its entry into this sophisticated industrialisation only two or three decades back. It is also heartening to see that policy directions which have guided the growth of the industry have by and large proved to be correctly oriented to serve optimally our needs, and are in tune with our endowments and resources. A lot of good work is being done to meet the challenges of the difficult times ahead. One could confidently hope that with the experience already built up and the capabilities already developed, the country will be able to meet the future needs of this industry with as much skill and success as it has done in the past.

Table I

GROWTH OF NITROGENOUS FERTILIZER CAPACITY

'000 te N/yr (No. of units)

Year	Public Sector	Private Sector	Cooperative Sector	Total
1947-48 . . .	10 (2)	—	—	10 (2)
1951-52 . . .	85 (2)	—	—	85 (2)
1956-57 . . .	89 (3)	—	—	89 (3)
1959-60 . . .	136 (4)	14 (2)	—	150 (6)
1960-61 . . .	228 (5)	14 (2)	—	242 (7)
1962-63 . . .	359 (6)	14 (2)	—	373 (8)
1963-64 . . .	359 (6)	22 (3)	—	381 (9)
1965-66 . . .	526 (10)	22 (3)	—	548 (13)
1967-68 . . .	640 (11)	209 (5)	—	849 (16)
1968-69 . . .	685 (12)	339 (6)	—	1024 (18)
1969-70 . . .	685 (12)	659 (7)	—	1344 (19)
1971-72 . . .	805 (13)	659 (7)	—	1464 (20)
1973-74 . . .	1109 (15)	830 (8)	—	1939 (23)
1975-76 . . .	1164 (16)	1130 (9)	215 (1)	2509 (26)
1976-77 . . .	1520 (19)	1293 (10)	215 (1)	3028 (30)
1978-79 . . .	1751 (19)	1293 (10)	215 (1)	3259 (30)
1979-80 . . .	2383 (21)	1293 (11)	215 (1)	3891 (33)
1980-81 . . .	2838 (23)	1294 (11)	443 (2)	4595 (36)

Table II

GROWTH OF PHOSPHATIC FERTILIZERS

'000 te P_2O_5/yr (No. of units)

Year	Public Sector	Private Sector	Cooperative Sector	Total
1906-07 . . .	—	6 ·4 (1)	—	6 ·4 (1)
1913-14 . . .	—	7 ·4 (2)	—	7 ·4 (2)
1924-25 . . .	—	19 ·1 (3)	—	19 ·1 (3)
1941-42 . . .	—	24 ·5 (4)	—	24 ·5 (4)
1946-47 . . .	—	42 ·7 (6)	—	42 ·7 (6)
1947-48 . . .	—	48 ·1 (7)	—	48 ·1 (7)
1948-49 . . .	7 ·2 (1)	48 ·6 (8)	—	55 ·8 (9)
1950-51 . . .	7 ·2 (1)	56 ·3 (10)	—	63 ·5 (11)
1957-58 . . .	10 (2)	69 ·6 (11)	—	79 ·5 (13)
1959-60 . . .	10 (2)	74 ·9 (12)	—	84 ·9 (14)
1960-61 . . .	14 (2)	81 ·3 (14)	—	95 ·3 (16)
1961-62 . . .	14 (2)	102 ·5 (16)	—	116 ·5 (18)
1962-63 . . .	17 (2)	131 ·4 (20)	—	148 ·4 (22)
1963-64 . . .	17 (2)	161 ·4 (24)	—	178 ·4 (26)
1965-66 . . .	60 (3)	167 ·9 (25)	—	227 ·9 (28)
1967-68 . . .	92 ·2 (4)	311 ·4 (28)	—	403 ·6 (32)
1971-72 . . .	117 ·2 (5)	322 ·8 (29)	—	500 (34)
1975-76 . . .	187 ·2 (5)	377 ·8 (32)	127 (1)	692 (38)
1976-77 . . .	418 ·2 (6)	459 ·8 (34)	127 (1)	1005 (41)
1978-79 . . .	643.2 (6)	459 ·8 (34)	127 (1)	1230 (41)
1979-80 . . .	665 (6)	480 (34)	127 (1)	1272 (41)
1980-81 . . .	665 (6)	490 (34)	127 (1)	1282 (41)

Table III

N CAPACITY DISTRIBUTION—FEEDSTOCKWISE

'000 te N

(% of total in each col.)

Feedstock	Capacity operating in 1981	Capacity under construction in 1981	Planned provision upto 1990	Total as expected in operation in 1990
Natural Gas . .	502 (11%)	1705	2058	4265 (42·7%)
Naphtha . . .	2425 (53%)	100	343	2868 (28·7%)
Electric Power . .	80 (1·8%)	—	—	80 (0·8%)
Coke/coke Oven Gas .	86 (1·9%)	—	—	86 (0·9%)
Coal . . .	456 (10%)	—	228	684 (6·9%)
Fuel Oil . . .	911 (19·9%)	425	228	1564 (15·6%)
Imported Ammonia .	115 (2·4%)	50	273	438 (4·4%)
TOTAL . . .	4575 (100%)	2280	3130	9985 (100%)

Table IV

PRODUCT-WISE CAPACITY AS IN 1981

Product	Grade	Capacity in terms of	
		'000 te N	'000 te P_2O_5
Straight Nitrogen			
Urea	46% N	3680	—
Ammonium sulphate	20·6% N	191	—
Calcium ammonium nitrate	25% N	200	—
Ammonium chloride	25% N	14	—
Straight Phosphates			
Single superphosphate	16% P_2O_5	—	246
Triple superphosphate	46% P_2O_5	—	240
NP or NPK complexes			
Ammonium phosphate-sulphate	16—20—0 20—20—0	49	54
Nitrophosphate	20—20—0 15—15—15	120	120
Urea ammonium phosphates	28—28—0 17—17—17 14—35—14 24—24—0 19—19—19 14—28—14	218	372
Diammonium phosphate (DAP)	18—46—0	53	123
DAP based NPKs	10—26—26 12—32—16	50	127
		4575	1282

Table V

TECHNIQUES EMPLOYED

A. *AMMONIA*

1. Raw gas generation feedstock	Process	Catalysts/systems used
(a) Natural gas/ naphtha	Catalytic Steam Reforming using top/side fired furnaces	ICI/Haldor Topsoe/ UCIL/FPDIL
(b) Fuel Oil/naphtha	Non-catalytic Partial oxidation	Texaco/Shell BIPM
(c) Coal . .	Gasification of entrained coal dust	Kopper Totzek
(d) Water/air .	Electrolysis + Air fractionation	De Nova
(e) Coke oven gas	Gas fractionation	Linde
(f) Coke . .	Semi water gas generators	Pintsch Bamag
2. Acid gas (CO_2/hrs.) Removal . .	(a) Monoethanolamine wash	
	(b) Hot potash wash	With additives/inhibitors in Benefield system
	(c) Caustic wash	
	(d) Methanol wash	Rectisol by Lurgi/Linde
3. Ammonia synthesis	Haber Botsch or its variations	ICI/Montidison/ Chemico/TEC/Kellog/ Haldor Topsoe/Grand Parroise
B. *UREA* .	(a) Absorption/separation	Vulcan
	(b) Solution recycle —Conventional —Stripping	Montedison/Mitsui Toatsu/Stamicarbon Stamicarbon/SNAM Progetti.

C. *SULPHURIC ACID*	(a) Conventional	DMCC/FEDO/FPDIL
	(b) DCDA	DMCC/Simon Caryes Chemie Bau
	(c) Pyrites/metallurgical gas based	Lurgi Chemie Bau
D. *AMMONIUM SULPHATE*	(a) Direct neutralisation of acid	
	(b) Gypsum route by Mersebery Reaction	
	(c) Byproduct recovery	
E. *CALCIUM AMMONIUM NITRATE*		
F. *PHOSPHORIC ACID*	(a) Dihydrate	Prayon/Chemico/Dorr Oliver
	(b) Hemihydrate	Nissan/Central Prayon
G. *AMMONIUM PHOSPHATE/NPKs*		Dorr Oliver Hitachi Zosen
H. *NITROPHOSPHATES*	(a) Phosphonitric	Chemical & Industrial Corporation, USA
	(b) Odda	Uhde/Stamicarbon
	(c) Sulphate recycle	Stamicarbon

Table VI

OUTPUT VERSUS CAPACITY

'000 te N/P_2O_5

Year	N		P_2O_5	
	Capacity	Production	Capacity	Production
1951-52 . . .	85	53	63·5	10
1955-56 . . .	89	80	79·5	12
1960-61 . . .	242	98	95·3	52
1965-66 . . .	548	233	227·9	111
1971-72 . . .	1464	949	500	290
1975-76 . . .	2509	1535	692	320
1977-78 . . .	3028	2000	1005	670
1978-79 . . .	3259	2173	1230	778
1979-80 . . .	3891	2226	1272	757
1980-81 . . .	4594	2164	1282	841. 5

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